PATTERNED QUANTUM DOT AND INVERSE QUANTUM DOT ACTIVE LAYERS FOR OPTOELECTRONICS APPLICATIONS

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The use of semiconductor quantum dots (QDs) in photonic devices has become widespread in recent years and QDs themselves have received a considerable amount of attention from the photonics community. Not only do they offer many potential advantages in lasers, but they have also become interesting from an applied physics perspective as tools for exploring strong coupling in nanoscale cavities, as single photon emitters, and possibly as elements of quantum information circuits. To a great extent many of the promises made about the advantages QDs would bring to photonic devices remain unfulfilled, largely due to the size inhomogeneity and random placement inherent with the self-assembled growth technique. The work in this document demonstrates that it is possible to create patterned QDs with precisely engineered properties such as diameter, thickness, material composition, position, and emission wavelength, while simultaneously maintaining the high optical quality of the material necessary for incorporation into optoelectronic devices. These QDs are fabricated using electron beam lithography combined with wet-etching and regrowth techniques.

We also present a detailed theoretical analysis of a novel structure which can only be formed by patterning techniques known as the nanopore or inverse quantum dot structure. This structure is the electronic analogue of a photonic crystal. We show that the perturbation of an ordinary quantum well by a periodic two-dimensional lattice of energy barriers leads to the introduction of intraband energy gaps. The predicted results show

excellent agreement with experimental data obtained from devices fabricated by selective area epitaxy. In addition, we have explored the use of the wet-etching technique for the fabrication of this nanostructure. The wet-etching technique is shown to provide a higher degree of flexibility and repeatability than the selective area epitaxy process. The experimental results suggest a significant reduction in intersubband scattering rates resulting in a drastic modification of the interband optical properties, which may be useful for the utilization of the nanopore structure in intersubband devices. This observation is supported by analytical calculations of the electron-phonon scattering rates in the nanopore structure.